8.0 BASELINE HUMAN HEALTH RISK ASSESSMENT SUMMARY

~~The BHHRA is an analysis of potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases. The BHHRA is intended to provide information to risk managers on potential risks to human health that are associated with contaminants originating from and present at the Site. Under CERCLA, the BHHRA is one of several pieces of information that is used by risk managers to inform their decisions about potential risks associated with a given site, as well as what can be practically done to reduce risks that may be deemed unacceptable. Other sources of information weighed by risk managers are the ecological risk assessment, fate and transport modeling for sediment, stormwater and other sources of chemicals from outside the Site, as well as various engineering considerations on the feasibility of certain remedial alternatives that can be implemented to reduce risk. The BHHRA is also used to support development of PRGs for protection of human health.~~

~~The LWG has worked with EPA to develop the methods and assumptions used in the BHHRA. Consistent with EPA guidance (1989), the BHHRA has been developed to provide a conservative (i.e., health-protective) assessment of risks associated with contaminants present at the Site. The results of this BHHRA should be weighed in a measured and informed fashion in light of the health-protective assumptions.~~The Baseline Human Health Risk Assessment (BHHRA) presents an evaluation of risks to human health at the Portland Harbor Superfund Site. It is intended to provide an analysis of baseline risks and help determine the need for action at the Site, and to provide risk managers with an understanding of the actual and potential risks to human health posed by the site and any uncertainties associated with the assessment.

~~The LWG has worked with EPA to develop the methods and assumptions used in the BHHRA.~~ Consistent with EPA guidance (1989), ~~it~~the BHHRA incorporates assumptions to provide a health protective assessment of risks associated with contaminants present at the Site. The risk assessment for Portland Harbor is a baseline risk assessment in that it evaluates human health risks and hazards associated with contamination in the absence of remedial actions or institutional controls. Th~~ise~~ BHHRA ~~generally~~ follows the approach that was documented in the Programmatic Work Plan (Integral et al. 2004) and subsequent interim documents. It also reflects numerous discussions and agreements on appropriate risk assessment techniques for the Site among interested parties, including the EPA, Oregon Department of Environmental Quality (DEQ), Oregon Department of Human Services (ODHS), and Native American Tribes.

Potential exposure pathways, populations, and exposure assumptions were originally identified in the Programmatic Work Plan and in subsequent direction from EPA. Additional assumptions for estimating the extent of exposure were provided in the Exposure Point Concentration Calculation Approach and Summary of Exposure Factors Technical Memorandum (Kennedy/Jenks Consultants 2006) and the Human Health

Toxicity Values Interim Deliverable (Kennedy/Jenks Consultants 2004a). The BHHRA is based on EPA (1989, 1991a, 2001b, 2004, 2005a) and EPA Region 10 (2000b) guidance, and is also consistent with DEQ guidance (DEQ 2000, 2010).~~The approach of the BHHRA is consistent with EPA (1986, 1989, 1991a, 2001b), Region 10 EPA (2000b), and DEQ (2000) HHRA guidance. The methods and inputs for the BHHRA reflect numerous discussions, directives, and agreements with interested parties, including EPA, DEQ, ODHS, and Native American Tribes. The BHHRA was conducted in accordance with the EPA-approved Programmatic Work Plan (Integral et al. 2004) and Human Health Interim Deliverables (Kennedy/Jenks 2004a,b,c; 2006). Additional exposure scenarios that were not included in the Programmatic Work Plan were also evaluated in the BHHRA based on documented direction from EPA, as discussed in Section 8.2.~~

The remainder of this section presents a summary of the methods used and results of the BHHRA, including the data evaluation, exposure assessment, toxicity assessment, risk characterization, uncertainty analysis, and conclusions. The complete BHHRA is presented in Appendix F to this RI report.

8.1 DATA EVALUATION

The sources of data available for use ~~use at the time of~~in the BHHRA are described in Section 2 of this RI Report. The use and evaluation of those data for purposes of the BHHRA are described in Section 2 of Appendix F~~ and in Attachment F2~~. Data from LWG and non-LWG sampling events were included in the SCRA database, a subset of which was used for the BHHRA. Only data that meet QA2Cat1 data quality objectives were used in the BHHRA. D~~Also, the ~~ata collected between RM 1.0, including Multnomah Channel and upstream to RM 12.2 were included in the risk assessment~~BHHRA only included data collected between RM 1.0 and RM 12.2, including Multnomah Channel~~. Samples collected between RM 1.9 and RM 11.8 were considered to be within the Study Area, which was the focus of the BHHRA. ~~Samples collected outside of the Study Area were evaluated separately in the BHHRA per an agreement with EPA. ~~The following summarizes the data used in the BHHRA by medium:

- **Beach Sediment:** Composite beach sediment samples that were collected from designated human use areas within the Study Area~~ were included in the BHHRA data set~~.
- **In-water Sediment:** In-water sediment (i.e., not beach sediment) samples that were collected from the top 30.5 cm in depth between the bank and the navigation channel~~ were included in the BHHRA data set~~.
- **Surface Water:** All Round 2 and Round 3 surface water data collected from the Study Area, as well as Multnomah Channel~~, were included in the BHHRA data set~~.
- **Groundwater Seep:** Data from Outfall 22B, which discharges in a potential human use area~~, were included in the BHHRA data set~~. ~~Samples ~~However, samples

collected from this outfall as part of a stormwater sampling event were excluded ~~from the BHHRA groundwater seep data set~~.

- **Fish Tissue:** Composite samples, both whole body and fillet with skin (fillet without skin samples were analyzed for mercury only), of target resident fish species (smallmouth bass, brown bullhead, black crappie, and common carp~~) were included in the BHHRA data set.~~ Composite samples of adult Chinook salmon (whole body, fillet with skin, and fillet without skin), adult lamprey (whole body only), and sturgeon (fillet without skin only) were also included in ~~the BHHRA data set~~for evaluation of consumption by tribal members.
- **Shellfish Tissue:** C~~Field-collected c~~omposite samples of crayfish and clam tissue, ~~(~~depurated and undepurated~~) were included in the BHHRA data set~~.

Because of the large number of chemicals detected in environmental media, a risk-based screening approach was used to focus the risk assessment on those contaminants most likely to significantly contribute to the overall risk. COPCs were selected for quantitative evaluation in the BHHRA by comparing the SCRA analytical data to risk-based screening values. ~~COIs are all contaminants that were detected in environmental media during investigations within the Study Area. EPA guidance (1989) recommends considering criteria to limit the number of contaminants that are included in a quantitative risk assessment while also ensuring that all contaminants that may contribute significantly to the overall risk are addressed. The contaminants included in the BHHRA for quantitative evaluation are the COPCs. For the purposes of the BHHRA, a comparison to risk-based screening levels was used to select COPCs for further evaluation. COPCs were selected for a medium based on a subset of data determined to represent exposure to a specific human population.~~ If the maximum detected concentration of a ~~COI~~ chemical ~~for a given exposure scenario~~ exceeded ~~the~~ its appropriate risk-based screening level, or if a risk-based screening level was not available, the contaminant was selected as a COPC.

8.2 EXPOSURE ASSESSMENT

The ~~objectives of the~~ exposure assessment consists of three primary tasks:

- Characterization of the exposure setting. This step includes identifying the characteristics of populations that can influence their potential for exposure, including their location and activity patterns, current and future land use considerations, and the possible presence of any sensitive subpopulations.
- Identification of exposure pathways. Exposure pathways are identified for each population by which they may be exposed to chemicals originating from the site.
- Quantification of exposure. The magnitude, frequency, and duration of exposure for each pathway is determined. This step consists of the estimating of exposure point concentrations and calculation of chemical intakes.

8.2.1 Conceptual Site Model

~~were to identify potentially exposed receptor populations, identify and characterize exposure pathways, and estimate the extent of exposure for pathways that are potentially complete and significant. The exposure assessment for the BHHRA is found in Section 3 of Appendix F. Additionally,~~ The conceptual site model (CSM) describes potential contaminant sources, transport mechanisms, potentially exposed populations, exposures pathways and routes of exposure. ~~Figure 8.2-1 shows the CSM for the BHHRA, which summarizes all of the exposure scenarios that were evaluated in the BHHRA.~~

~~Only potentially complete and significant exposure pathways were quantitatively evaluated for risk in the BHHRA (see Figure 8.2-1).~~ Currently or potentially exposed populations were identified based on consideration of both current and potential future uses of the Study Area, and include populations who may be exposed to contamination though a variety of activities. Exposure pathways are defined as the physical ways in which chemicals may enter the human body. A complete exposure pathway consists of the following four elements:

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- A source of chemical release
- A release or transport mechanism (or media in cases involving media transfer)
- An exposure point (a point of potential human contact with the contaminated exposure medium)
- An exposure route (e.g., ingestion, dermal contact) at the exposure point.

If any of the above elements is missing, the pathway is considered incomplete and exposure does not occur. The relevant potential exposure pathways to human populations at the Study Area include:

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- Incidental ingestion of and dermal contact with beach sediment
- Incidental ingestion and dermal contact with in-water sediment
- Incidental ingestion and dermal contact with surface water
- Incidental ingestion and dermal contact with surface water from seeps
- Consumption of fish and shellfish
- Infant consumption of human milk

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8.2.2 Identification of Potentially-Exposed Populations

The specific populations and exposure pathways evaluated in the BHHRA were as follows:

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- ~~The following are the populations~~ Dockside workers — direct exposure via incidental ingestion and dermal contact with beach sediments.

- In-water workers — direct exposures to in-water sediment.
- Transients — direct exposure to beach sediment, surface water for bathing and drinking water scenarios, and groundwater seeps.
- Recreational beach users — direct exposure to beach sediment and surface water while for swimming.
- Tribal fishers — direct exposure to beach or in-water sediments, and consumption of migratory and resident fish.
- Recreational and subsistence fishers — direct exposure to beach or in-water sediments, consumption of resident fish, and consumption of shellfish.
- Divers — direct exposure to in-water sediment and surface water.
- Domestic water user — direct exposure to untreated surface water potentially used as a drinking water source in the future.
- Infant consumption of human breast milk — exposure to certain persistent and bioaccumulative contaminants (PCBs, DDx compounds, dioxins and furans, and PBDEs) via nursing infants of dockside and in-water workers, divers, and recreational, subsistence, and tribal fishers

~~and associated exposure scenarios that were quantitatively evaluated in the BHHRA:~~

~~**Dockside Worker** — Direct exposure to (i.e., ingestion of and dermal contact with) beach sediment, infant ingestion of human breast milk.~~

~~**In-water Worker** — Direct exposure to in-water sediment, infant ingestion of human breast milk.~~

~~**Adult and Child Recreational Beach User** — Direct exposure to beach sediment and surface water (for swimming scenarios).~~

~~**Transient** — Direct exposure to beach sediment, surface water (for bathing and drinking water scenarios), and groundwater seeps.~~

~~**Diver** — Direct exposure to in-water sediment and surface water, infant ingestion of human breast milk.~~

~~**Tribal Fisher** — Direct exposure to beach sediment or in-water sediment, fish consumption, and infant ingestion of human breast milk.~~

~~**Fisher** — Direct exposure to beach sediment or in-water sediment, fish consumption, shellfish consumption, and infant ingestion of human breast milk.~~

~~**Domestic Water User** — direct exposure to untreated surface water hypothetically used as a drinking water source in the future.~~

Exposures were evaluated on a Study Area-wide basis, as well as on more localized spatial scales as appropriate for each exposure scenario. Exposure~~s~~ to beach sediment ~~were~~ was assessed per beach, ~~and~~ exposure~~s~~ to groundwater seeps ~~were~~ was assessed per seep. Exposure~~s~~ to in-water sediment, surface water, and fish and shellfish tissue ~~were~~ was assessed on both localized and Study Area-wide scales. Except where specifically noted, the exposure assumptions used in the BHHRA were applied uniformly to all of the Study Area, and may or may not be applicable at specific locations within the Study Area depending on factors not specifically addressed in the BHHRA ~~(e.g., accessibility, habitat)~~. ~~The actual exposure at a given location may be less than that assumed for the population and Study Area as a whole due to location-specific conditions.~~

Consistent with EPA policy, the exposure assessment evaluated a reasonable maximum exposure (RME), which is defined as the maximum exposure that is reasonably expected to occur. In addition, estimates of central tendency (CT), which are intended to represent average exposures, were also evaluated. Assumptions about each population were used to select exposure parameters to calculate the pathway-specific chemical intakes. As site-specific values are not available to describe potential exposures for each populations and pathways, default values representative of the larger U.S. population were used. Where default values are not available, best professional judgment was used ~~by EPA~~ based on likely activity patterns.

8.2.3 Exposure Point Concentrations

Exposure point concentrations (EPCs) were calculated to represent the average concentration contacted over the duration of the exposure. The average is used to represent "a reasonable estimate of the concentration likely to be contacted over time" (EPA 1989). EPA guidance (EPA 1989, 1992) recommends that the 95 percent upper confidence limit (UCL) on the arithmetic mean should be used to represent the average because of the uncertainty associated with estimating the true average concentration at a site. The maximum reported concentration was used in instances where there were insufficient data to calculate a UCL, or the calculated UCL was greater than the maximum reported value. The simple mean was used as the EPC in sediment and surface water for the CT evaluations.

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8.2.4 Estimation of Chemical Intakes

The amount of each chemical incorporated into the body is defined as the dose and is expressed in units of milligrams per kilogram per day (mg/kg-day). The dose is calculated differently when evaluating carcinogenic effects than when evaluating noncarcinogenic effects.

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For non-occupational scenarios where exposures to children are considered likely, exposures to both adult and child were evaluated. Children often exhibit behavior such as outdoor play activities and greater hand-to-mouth contact that can result in greater exposure than for a typical adult. In addition, children also have a lower overall body weight relative to the predicted intake. As cancer risks are averaged over a lifetime, they are directly proportional to the exposure duration. Accordingly, a combined exposure from childhood through adult years was evaluated where appropriate, to account for the increased relative exposure and susceptibility associated with childhood exposures.

In general, Superfund exposure assessments ~~generally~~ assess RME by using a combination of 90th or 95th percentile values for contact rate, exposure frequency and duration, and 50th percentile values for other variables. CT estimates are ~~generally~~ done using average or median values for all variables.

For example, a range of fish consumption rates was evaluated using information from studies conducted in the Willamette and Columbia River basins, as well as from data representing the general U.S. population. A consumption rate of 17.5 g/day (approximately 2 eight ounce meals per month) was considered representative of a CT value for recreational fishers, 49 g/day and 142 g/day per day (approximately 7 and 19 eight ounce meals per month) were selected as the RME value representing the higher-end consumption practices of recreational fishers and for high levels of fish consuming, or subsistence, fishers, respectively.

The rates of 17.5 g/day and 142 g/day represent the 90th and 99th percentiles, respectively, of per capita consumption of uncooked freshwater/estuarine finfish and shellfish by individuals (consumers and non-consumers) 18 or older, as reported in the Continuing Survey of Food Intakes by Individuals (CSFII) and described in EPA's Estimated Per Capita Fish Consumption in the United States (EPA 2002b). The consumption rate of 49 g/day is from a creel study conducted in the Columbia Slough (Adolfson 1996), and represents the 95 percent upper confidence limit on the mean, where 50 percent of the mass of the total fish is consumed. Tribal consumption of a mixed diet consisting of both resident and anadromous fish was evaluated using a consumption rate of 175 g/day (approximately 23 eight oz meals per month), representing the 95th percentile of consumption rates from the Columbia River Inter-Tribal Fish Commission (CRITC, 1994) survey.

~~Several of the exposure scenarios were directed by the EPA, including exposure to divers, clam consumption, fish ingestion for single-species diets, and domestic water use. There is uncertainty to what extent each of these exposures occurs at the Site. Two diver exposure scenarios that differentiate between the use of either a wet suit or dry suit were included in the BHHRA as directed by the EPA. Also as directed by the EPA, consumption of clams was assessed as an exposure pathway. The abundance of clams is limited at the Site as demonstrated by the low numbers of clams found during~~

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~~sampling activities, which were predominantly Asian clams (*Corbicula* sp.). The possession and harvest of Asian clams is illegal in the State of Oregon. Even though surface water in the LWR within Portland Harbor is not currently used as a domestic water source, under OAR 340-041-0340 Table 340A, domestic water supply is a designated beneficial use of the Willamette River, with adequate pretreatment.~~

~~The exposure assessment incorporated the reasonable maximum exposure (RME) approach described by EPA (1989). The RME is intended to be a conservative exposure level that is still within the range of possible exposures. Consistent with EPA (1989), the exposure assessment also used CT values, which are intended to represent average exposures, for certain exposures that may occur within the Study Area. For some exposure scenarios, such as fish consumption, exposure assumptions were directed by EPA. Study Area-specific information is not available for fish consumption rates for specific species, so a range of ingestion rates and diets composed of various species were evaluated in the BHHRA for both adult and child consumers of fish. The ingestion rates used for an adult fisher of 17.5 g/day, 73 g/day, and 142 g/day are the same as approximately 2, 10, and 19 eight-ounce meals per month, respectively.~~

~~Exposure point concentrations (EPCs) were calculated for the 95% upper confidence limit on the arithmetic mean (95% UCL) and the arithmetic mean for each exposure area. In some exposure areas, the maximum concentration was used instead of the 95% UCL. Therefore, the EPCs are referred to as the 95% UCL/max and mean throughout the BHHRA.~~

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~~8.6~~8.3 TOXICITY ASSESSMENT

The toxicity assessment is composed of two steps: (1) hazard identification and (2) dose-response assessment. Hazard identification is a determination of whether exposure to a chemical may result in an adverse health effect in humans, consisting~~It consists~~ of characterizing the nature of the effect and the strength of the evidence that the chemical will cause the observed effect. ~~D~~The dose-response assessment characterizes the relationship between the dose and the incidence and/or severity of the adverse health effect~~ in the exposed population~~. For risk assessment purposes, chemicals are generally separated into categories based on ~~their toxicological endpoints. The primary basis of this categorization is, based on~~ whether a chemical exhibits ~~potentially~~ carcinogenic or noncarcinogenic health effects. ~~Because chemicals that are suspected carcinogens may also give rise to noncarcinogenic effects, they~~As appropriate, a chemical ~~must~~may be evaluated separately for both effects. Noncancer effects are evaluated using a reference dose (RfD). The RfD, expressed in units of mg of substance/kg body weight-day (mg/kg-day) is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population, including sensitive subgroups, that is likely to be without an appreciable risk of adverse effects resulting from a lifetime exposure. RfDs are based on the concept that ~~the range of~~ exposures less than the critical value are without adverse health effects. Carcinogenic effects are assessed using the cancer slope factor, which is typically expressed in units of per mg of substance/kg body weight-day ([(mg/kg-day)$^{-1}$]. The slope factor represents an upper

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The recommended hierarchy of toxicity values for use Superfund risk assessment is as follows (EPA 2003b):

- Tier 1 – EPA's Integrated Risk Information System (IRIS) database (EPA 2010b).
- Tier 2 - EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs) derived for use in the Superfund Program when ~~such~~ values are not available in IRIS.
- Tier 3 - EPA and non-EPA sources of toxicity information, with priority ~~is~~ given to those sources of information that are the most current, transparent and publicly available, and which have been peer reviewed. Tier 3 sources may include, but are not be limited to, the following sources:
  - The California Environmental Protection Agency (Cal EPA) Toxicity Criteria Database (Cal EPA 2008).
  - ATSDR Minimal Risk Levels.
  - EPA's Health Effects Assessment Summary Tables (HEAST).

~~Toxicity values provide a quantitative estimate of the potential for adverse effects resulting from exposure to a chemical. Toxicity values for both cancer and noncancer endpoints were evaluated. Toxicity values used in the BHHRA are presented in Section 4 of Appendix F. The following hierarchy of sources of toxicity values is currently recommended for use at Superfund sites (EPA 2003a), and was used for the BHHRA:~~

- ~~**Tier 1** EPA's Integrated Risk Information System~~
- ~~**Tier 2** EPA's Provisional Peer Reviewed Toxicity Values~~
- ~~**Tier 3** – Additional EPA and non-EPA sources of toxicity information.~~

~~Some toxicity values are based on exposure to chemical mixtures and not to individual chemicals. As a result, risks were evaluated for the combined exposure to the chemicals and not on an individual chemical basis for the following chemicals:~~

- ~~Total Chlordanes~~
- ~~Total DDD, Total DDE, and Total DDT~~
- ~~Total Endosulfan~~
- ~~Total PCBs~~

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- ~~Total Dioxins and Furans~~
- ~~Carcinogenic PAHs (assessed on both an individual and cumulative basis).~~

~~TEFs were used to evaluate carcinogenic and non-carcinogenic effects of dioxin and furan congeners and dioxin-like PCB congeners. PCBs were also evaluated as total PCBs for both carcinogenic and noncarcinogenic effects. Carcinogenic PAHs were evaluated for toxicity based on their PEF, which estimates toxicity relative to BAP (EPA 1993).~~

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~~8.21~~8.4 RISK CHARACTERIZATION

Risk characterization integrates the information from the exposure assessment and toxicity assessment, using a combination of qualitative and quantitative information. Risk characterization is performed separately for carcinogenic and noncarcinogenic effects. Carcinogenic risk is expressed as the incremental increased probability that an individual will develop cancer over a lifetime as a result of exposure to a potential carcinogen. Noncarcinogenic hazards are evaluated by comparing an estimated exposure level, or dose, with ~~a reference dose~~the RfD that is without appreciable risk of adverse health effects~~With this information, risk characterization estimates the potential health risk, based on the dose of a chemical that a person may receive under specific exposure conditions and the toxicity of that chemical.~~ ~~NConsistent with DEQ (2000) and EPA (1989) guidance, noncarcinogenic and carcinogenic effects were evaluated separately. COPCs were identified as contaminants potentially posing unacceptable risks if they resulted in a cancer risk greater than 1 x 10^{-6} or a hazard quotient (HQ) greater than 1 under the exposure scenarios and EPCs evaluated in this BHHRA, regardless of the uncertainties. The methods and results are described in detail in Section 5 of Appendix F and summarized below.~~

~~8.21.1~~8.4.1 ~~Methodology for~~ Risk Characterization Methodology ~~Methods~~

~~The potential for adverse effects resulting from exposure to contaminants with noncarcinogenic~~Noncarcinogenic effects ~~was~~ are addressed by comparing the estimated ~~absorbed~~ dose, as defined by the ~~(i.e.,~~ chronic daily intake, ~~)~~ ~~for a specific COPC~~ to ~~its~~ the corresponding ~~reference dose (~~RfD~~)~~ to yield a ~~HQ~~hazard quotient (HQ). ~~The~~ HQs for multiple chemicals ~~were~~ are summed across all ~~chemicals~~ relevant exposure pathways to calculate the cumulative hazard indices (HIs). ~~Per EPA (1989) guidance, HQs should be summed for chemicals with common toxicological endpoints. If~~Although a HI provides an overall indication of the potential for noncancer hazards, dose additivity is most appropriately applied to chemicals that induce the same effect via the same mechanism of action. When the HI is greater than 1 due the sum of several HQs of similar value, it is appropriate to segregate the chemical-specific HQs by toxicological effect and mechanism of action. When either the cumulative or the ~~When the cumulative HIs exceeded~~ ~~is greater than~~ ~~1, estimated endpoint-specific HIs were compared to a target HI of 1 for each exposure area, below which remedial action at a Superfund site is generally not warranted (EPA 1991b).~~effect-specific HI is less than 1, adverse health effects associated with the exposures are considered unlikely.

Potential cancer risks were assessed by multiplying the estimated ~~absorbed~~ dose by the ~~(i.e., lifetime average daily intake) of a carcinogen by its~~appropriate cancer slope factor. This calculated risk is expressed as the probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen, and is a conservative, health-protective estimate of the incremental probability of excess individual lifetime cancer risk. ~~Estimated total cancer risks (summed across all chemicals) were compared to 1 x 10^{-4}, 1 x 10^{-5}, and 1 x 10^{-6} cancer risk targets based upon the following language in EPA's National Contingency Plan (NCP): "For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 1 x 10^{-4} and 1 x 10^{-6}." The point of departure for cancer risks is 1 x 10^{-6}.~~

~~Cancer risks were calculated separately for adult and child receptors for the recreational beach user, domestic water user, and fisher scenarios. To assess risks to individuals exposed as both a child and an adult, cancer risks were also calculated for a combined adult and child receptor for the recreational beach user, domestic water user, and fisher scenarios.~~

Response~~For bioaccumulative chemicals, exposure to the mother can potentially lead to the presence of those chemicals in human milk, which can pose a risk to breastfeeding infants. Per agreement with EPA and DEQ, risks to infants through the consumption of human milk were included for all receptors where PCBs, dioxins, and/or DDx were identified as COPCs. To assess risks to infants, infant risk adjustment factors (IRAFs) were applied to the mother's risk for each of these contaminants. The approach and values for IRAFs used to assess risks to infants were in accordance with DEQ guidance (2010b).~~ actions under CERCLA are generally warranted when ~~where~~ the baseline risk assessment indicates a cumulative risk under either current or future ~~land use~~ exposure is greater than the upper end of the acceptable risk range of 1 x 10^{-4} to 1 x 10^{-6}, or when the HI is greater than 1. Accordingly, risk and hazard estimates are generally presented in terms of whether they are greater than 1 x 10^{-4} or ~~the HI is~~ greater than 1, respectively.

~~8.21.2~~8.4.2 Risk Characterization Results

The ranges of estimated potential risks resulting from the different exposure scenarios are summarized in Table 8.4-1. A summary of the risk characterization results is presented by exposure scenario in the following sections.

8.4.3 Dockside Workers

Risks to dockside workers were estimated separately for each of the eight beaches designated as a potential dockside worker use areas. The estimated cancer risks are less than 1 x 10^{-4} at all beach areas, and the HIs ~~is~~are less than 1 for adults and infants.

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8.4.4 In-Water Workers

In-water sediment exposure by in-water workers was evaluated in half-mile increments along each side of the river. The estimated CT and RME cancer risks are less than 1×10^{-4} at all RM segments, and the RME HIs for adults are less than 1 at ~~any~~all locations. The HI for infants at RM 7W is 2 due to dioxins and furans.

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8.4.5 Transients

Risks to transients were estimated separately for each beach designated as a potential transient use area, as well as for the use of surface water as a source of drinking water and for bathing. Year-round exposure to surface water was evaluated for four individual transect stations, Willamette Cove, Multnomah Channel, and for four transects grouped together to represent Study Area-wide exposure. The CT and RME risk estimates for beach sediment are less than 1×10^{-4} for all locations, and the HIs ~~is~~are less than 1. Estimated CT and RME cancer risks associated with surface water exposures, including ~~an evaluation of~~ surface water ~~use by transient populations~~from a groundwater seep at Outfall 22, ~~-~~are less than 1×10^{-4} at all locations, and the HIs ~~is~~are less than 1.

8.4.6 Divers

Commercial divers were evaluated for exposure to surface water and in-water sediment, ~~and~~ assuming the diver was wearing either a wet or a dry suit. In-water sediment exposure by divers ~~i~~was evaluated in half-mile exposure areas for each side of the river, and on a Study Area-wide basis. Risks associated with exposure to surface water were evaluated for four individual transect stations, and at single-point sampling stations grouped together in one-half mile increments per side of river.

The estimated CT and RME cancer risks associated with exposure to in-water sediments by divers wearing wet suits ~~is~~are less than 1×10^{-4} at all half-mile river segments as well as for Study Area-wide exposure, and the HIs ~~is~~are also less than 1 for adults. The HI for indirect exposure to infants of adult divers is 2 at RM 8.5W for the RME evaluation, due to PCBs. The estimated CT and RME cancer risks associated with exposure to surface water ~~is~~are less than 1×10^{-4} for all half-mile river segments, and the HIs ~~is~~are less than 1. ~~Diver in Dry Suit~~

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The estimated RME cancer risk associated with exposure to in-water sediments and surface water by divers wearing dry suits is less than 1×10^{-4} at all half-mile river segments and for Study Area-wide exposure, and the HI is also less than 1 for adults and indirect exposures to infants via breastfeeding.

8.4.7 Recreational Beach Users

Risks associated with exposure to beach sediment were evaluated separately for each beach designated as a potential recreational use area, and exposure to surface water was evaluated using data collected from three transect locations and three single-point locations at Cathedral Park, Willamette Cove, and Swan Island Lagoon. Estimated CT

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and RME cancer risks associated with exposure to beach sediments and surface water are less than 1 x 10^{-4} at all recreational beach areas, and the HIs ~~is~~are also less than 1. Indirect exposures to infants via breastfeeding were not evaluated.

8.4.8 Recreational/Subsistence Fishers

Recreational and subsistence fishers were evaluated assuming direct exposure to contaminants in sediment and via consumption of fish and shellfish. Exposures associated with beach sediment were assessed at individual beaches designated as potential transient or recreational use areas, in-water sediment exposures were evaluated on a one-half river mile basis per side of the river and as an averaged, Study Area-wide evaluation. Sediment exposures were further assessed as CT and RME evaluations and assuming either a low- or a high-frequency rate of fishing.

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Estimated CT and RME cancer risks associated with both low- and high-frequency fishing exposures to either beach or in-water sediments are less than 1 x 10^{-4} at all areas evaluated. ~~Noncancer hazard~~HIs associated with adult exposures to beach ~~or in-water~~ sediment are less than 1 at all locations evaluated. ~~-~~The RME ~~noncancer hazard~~HI~~s~~ associated with adult exposures to in-water sediment ~~are~~is greater than 1 at RM 7W for high-frequency fishing; HIs for all other locations and fishing exposures are less than 1. The RME ~~noncancer hazard~~HI associated with indirect exposures of in-water sediment contamination to infants via breastfeeding is greater than 1 at RM 7W and RM 8.5W. Indirect exposure to contaminants in beach sediment to infants was not evaluated.

Consumption of resident fish species was evaluated on a river mile basis using smallmouth bass data as a surrogate for all fish consumed. Consumption of fish was also evaluated over the entire Study Area assuming a diet consisting of equal ~~fillet~~ proportions of common carp, brown bullhead, back crappie, and smallmouth bass. Consumption on a river mile basis was evaluated only for recreational fishers, consumption averaged over the entire Study Area was evaluated for both recreational and subsistence fishers. With the exception of RM 5, RME risk estimates on a river mile basis are all greater than 1 x 10^{-4}. CT estimates are greater than 1 x 10^{-4} at RM 7, Swan Island Lagoon, and RM 11. River miles exhibiting the highest estimated RME risks are: RM 2 (2 x 10^{-4}), RM 4 (3 x 10^{-4}), RM 7 (6 x 10^{-4}), Swan Island Lagoon (6 x 10^{-4}), RM 9 (2 x 10^{-4}), and RM 11 (1 x 10^{-3}). Study Area-wide RME risks for recreational and subsistence fishers are 4 x 10^{-3} and 1 x 10^{-2}, respectively; the Study Area-wide CT estimate for recreational fishers is 1 x 10^{-3}.

RME and CT ~~hazard estimate~~HIs are greater than 1 at all river miles. River miles exhibiting the highest estimated ~~RME hazard~~HIs are RM 4, RM 7, Swan Island Lagoon, and RM 11. Study Area-wide RME ~~hazard~~HIs for recreational and subsistence fishers are 300 and 1,000, respectively, the CT estimate for recreational fishers is 100.

RME ~~and CT noncancer hazard~~HIs associated with indirect exposure to infants via breastfeeding range from 30 to 1,000~~.~~, and CT estimates range from 10 to 500, when assessed on a river mile scale. Study Area-wide, the ~~hazard estimate~~HIs for recreational fishers are 2,000 and 4,000 for the CT and RME estimates, respectively, the RME ~~estimate~~HI for subsistence fishers is 10,000. River miles exhibiting the greatest RME ~~hazard estimate~~HIs are: RM 2 (200), RM 4 (200), RM 7 (200), Swan Island Lagoon (600), and RM 11 (1,000). The majority of the hazard estimates is attributable to PCBs.

EPCs on a river mile scale use data from smallmouth bass to represent contaminant concentrations in all resident fish species, ~~while~~and consumption was assumed to consist primarily of just the fillet rather than other parts of the fish. However, an evaluation of the data collected from Portland Harbor indicates that PCB concentrations in whole body smallmouth bass are typically an order of magnitude greater than those measured in just the fillet. By contrast, in common carp and brown bullhead, the observed ratio of whole body-to-fillet PCB concentrations is less than noted in smallmouth bass, meaning that given the same overall PCB concentration in whole body fish, the PCB concentration in smallmouth bass fillet tissue will be less than for carp and bullhead. These differences are reflected in the exposure concentrations such that the use of fillet smallmouth bass data on a river mile scale resulted in a greater relative reduction of PCB concentration than would be seen if fillet data from common carp and brown bullhead were included. A diet that consists of some portion of carp and bullhead could result in relatively greater intake of PCBs, and the associated risk and hazard would be correspondingly greater as well. In addition, at least some of the fishers in the Portland Harbor area consume more than just the fillet. Consumption of other portions of the fish in addition to the fillet can result in greater relative exposure to PCBs and other persistent bioaccumulative chemicals and thus, greater relative risks.

8.4.8.1 Consumption of ~~Clam~~Shellfishs

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Risks from consumption of clams and crayfish were evaluated for subsistence fishers. Estimated RME cancer risks associated consumption of undepurated clams by subsistence fishers are greater than 1 x 10^{-4} at 10 of the 22 river mile sections evaluated. The estimated risk Study Area-wide is 4 x 10^{-4}. Carcinogenic PAHs ~~contribute to the majority of the estimated~~pose the highest risks at RMs 5W and RM 6W, while PCBs ~~contribute to a majority of~~pose the highest risks in Swan Island Lagoon~~,~~ and RM 11~~,~~. Carcinogenic PAHs and PCBs pose the highest risks~~and~~ on a Study Area-wide basis. Estimated CT cancer risks are all less than 1 x 10^{-4}. ~~Estimated r~~Risks based on depurated clams w~~as~~ere estimated at RM 1E, RM 2W, RM 10W, RM 11E, and RM 12E, and none of the estimated CT or RME cancer risks are greater than 1 x 10^{-4}. The estimated RME ~~noncancer hazard~~HIs associated consumption of undepurated clams by subsistence fishers are greater than 1 at 20 of the 22 river mile sections evaluated, as well as when evaluated on a Study area-wide basis. RME ~~noncancer hazard~~HIs associated with indirect exposure to infants via breastfeeding ~~is~~are greater than 1 at each river mile evaluated.

~~Consumption of Crayfish~~

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The estimated RME cancer risks associated consumption of crayfish by subsistence fishers are greater than 1 x 10^{-4} at RM 7W and RM 11E, as well as on Study Area-wide basis. All estimated CT cancer risks are less than 1 x 10^{-4}.

The estimated RME ~~noncancer hazard~~HIs associated consumption of crayfish by subsistence fishers are greater than 1 at seven of the 32 individual stations, the estimated ~~noncancer hazard~~HI Study Area-wide is 10. RME ~~noncancer hazard~~HIs associated with indirect exposure to infants via breastfeeding ~~is~~are greater than 1 at 23 of the 32 stations evaluated, the HI is 200 when evaluated Study Area-wide.

8.4.9 Tribal Fishers

Exposures to tribal fishers were evaluated assuming direct contact with contaminants in sediment and via consumption of fish. Exposures associated with beach sediment were assessed at individual beaches, in-water sediment exposures were evaluated on a one-half river mile basis per side of the river and as an averaged, Study Area-wide evaluation. Fish consumption was evaluated assuming a multi-species diet consisting of anadromous and resident fish species, and fishing was evaluated on a Study Area-wide basis.

The estimated CT and RME cancer risks associated with direct contact to beach sediment is less than 1 x 10^{-4} at all beaches evaluated~~,~~. RME cancer risk associated with exposure to in-water sediment is greater than 1 x 10^{-4} at RM 6W and RM 7W~~ (3 x 10^{-4})~~. With the exception of in-water sediment exposure at RM 7W, the estimated ~~non-cancer hazard is~~HIs are less than one at all beach and in-water locations evaluated. Noncancer CT and RME ~~hazard estimates~~HIs associated with indirect exposure to infants via breastfeeding w~~as~~ere evaluated assuming maternal exposure to in-water sediment. The estimated RME ~~hazard~~HI is greater than 1 at RM 7W, RM 8.5, and RM 11E.

The estimated RME cancer risk~~s~~ for tribal consumption of fish is 2 x 10^{-2} assuming whole body consumption, and 1 x 10^{-2} assuming consumption of fillets only. RME ~~noncancer hazard~~HI associated with childhood consumption of whole body fish is 800, and is 600 assuming consumption of fillets only. RME ~~noncancer hazard~~HI associated with indirect exposure of tribal infants via breastfeeding assuming maternal consumption of whole body fish is 9,000, and is 8,000 assuming maternal fillet-only consumption.

8.4.10 Domestic Water Use

Use of surface water as a source of household water for drinking and other domestic uses was evaluated using data from five transect and 15 single point sampling locations, as well as averaged over a Study Area-wide basis. The estimated cancer risk for combined child and adult exposures is greater than 1 x 10^{-4} at RM 6W.

The estimated ~~noncancer hazard~~HIs based on childhood exposure ~~is~~are equal to or greater than 1 at several sampling locations: W005 (1) at RM 4, W023 (1) at RM 11, W027 (2) near the mouth of Multnomah Channel, and W035 (2) in Swan Island Lagoon. In all instances, MCPP is the primary contributor to the estimated hazard. ~~These results are presented in Tables 5-53 and 5-54.~~

8.4.11 ~~c~~Cumulative ~~r~~Risk ~~e~~Estimates

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Cumulative risk and hazard estimates were calculated for those populations where concurrent exposure to more than one media was assumed to be plausible. Recreational/subsistence and tribal fishers were further ev aluated on the basis of whether they were assumed to fish predominately from the shore or from a boat. Populations for which concurrent exposure to more than one media was considered for are as follows:

- Transients: Beach sediment, surface water
- Divers: In-water sediment, surface water
- Recreational beach users: Beach sediment, surface water
- Recreational fishers (beach): Beach sediment, fish tissue (fillet)
- Recreational fishers (boat): In-water sediment, fish tissue (fillet)
- Subsistence fishers (beach): Beach sediment, fish tissue (fillet), shellfish tissue
- Subsistence fishers (boat): In-water sediment, fish tissue (fillet), shellfish tissue
- Tribal fishers (beach): Beach sediment, fish tissue (fillet and whole body)
- Tribal fishers (boat): In-water sediment, fish tissue (fillet and whole body)

Cumulative risk estimates were generally calculated for each one-half river mile per side of the river, and the risk estimates for specific media appropriate to each one-half mile segment were used to calculate the total risk or hazard. For example, cumulative risks for recreational fishers who fish from a boat and consume smallmouth bass would include the risks associated with exposure to in-water sediment at the specific half-mile~~, shellfish collected within same half-mile and side-of-river specific segment,~~ and smallmouth bass from the larger river mile assessment. Risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment, surface water, or seeps. PCBs are the primary contributor to risk from fish consumption harbor wide. When evaluated on a river mile scale, dioxins/furans are a secondary contributor to the overall risk and hazard estimates. PCBs are the primary contributors to the noncancer hazard to nursing infants, primarily because of the bioaccumulative properties of PCBs and the susceptibility of infants to the developmental effects associated with exposure to PCBs.

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~~8.21.2.1 Fish Consumption~~

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~~Risks were calculated for the adult and child fishers who consume fish caught within the Study Area, as well as breastfeeding infants of mothers consuming fish, based on the following:~~

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- ~~Three different ingestion rates representing a range of consumption scenarios~~
- ~~Both single species and multiple species diets (black crappie, common carp, brown bullhead, and smallmouth bass)~~
- ~~Consumption of both whole body and fillet tissue.~~

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~~Risks were also evaluated for adult and child tribal fishers who consume fish as a multi-species diet consisting of resident fish species (black crappie, common carp, brown bullhead, and smallmouth bass) as well as sturgeon, lamprey, and salmon; and on consumption of both whole body and fillet with and without skin tissue. All risk estimates were made using both mean and 95 percent UCL/max estimates of contaminant concentrations in tissue. Consequently, minimum risk estimates represent the lowest consumption rate used for the scenario and mean tissue concentrations, and maximum estimates represent the highest consumption rate and 95 percent UCL/max tissue concentrations.~~

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~~The cancer risks for all of the fish consumption scenarios range from 3 x 10~~$^{-6}$ ~~(child consumption) to 7 x 10~~$^{-2}$ ~~(combined adult/child consumption). Cumulative HIs for all of the fish consumption scenarios ranged from 0.5 (adult consumption) to 5,000 (child consumption). The maximum cumulative HI for a breastfeeding infant of a fish consumer is 60,000. For many of the fish consumption scenarios, the cancer risks and noncancer hazards exceed the EPA target cancer risk range (10~~$^{-6}$ ~~to 10~~$^{-4}$~~) and target HI (1). The following summarizes the assumptions associated with the highest risk estimates:~~

- ~~**Fish ingestion rate.** The highest ingestion rates used in the BHHRA for adult tribal fishers and adult fishers are 175 g/day (CRITFC 1994) and 142 g/day (EPA 2002b), respectively. These are equivalent to 23 and 19 meals per month, respectively, based on an 8-ounce serving size, every month of the year exclusively of fish caught within the Study Area.~~
- ~~**Exposure duration.** Fish consumption is assumed to occur at that same rate for 30 years for adult fishers and 70 years for tribal fishers.~~
- ~~**Whole-body tissue.** Only whole-body tissue (i.e., the entire fish) is consumed.~~
- ~~**Single species.** Only one species (i.e., common carp) is consumed (for fishers).~~
- ~~**Source of fish.** 100 percent of the fish consumed is caught/harvested from the same localized exposure area.~~

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- ~~**Possible effects of cooking methods.** Possible effects of cooking methods, which can reduce concentrations of lipophilic chemicals in fish tissue, were not considered. PCB concentrations have been shown to be reduced from 10 to 87 percent with various cooking methods (Wilson et al. 1998).~~

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~~Site-specific fish consumption information is not available for the fisher scenarios. As a result, nationwide fish consumption data were used as the source for the fish ingestion rates used in the BHHRA. The specific ingestion rates used in the risk assessment were directed by EPA. If actual exposures within the Study Area were less than the assumptions provided above, estimated risks from consumption of fish would be lower.~~

~~PCBs and dioxins/furans contribute approximately 93 and 5 percent, respectively, of the estimated cumulative cancer risk for whole body, multi-species fish consumption for the Study Area. The remaining contaminants potentially posing unacceptable risks account for less than 2 percent of the cumulative cancer risk on a Study Area-wide basis. The contribution of contaminants to the cumulative cancer risks varies on a localized basis. PCBs also resulted in the highest HQs for the Study Area (up to 60,000 for the breastfeeding infant of a fisher consuming a whole-body carp tissue diet).~~

~~On a regional basis, risks from exposure to bioaccumulative compounds in tissue exceed the EPA target risk range of~~ 10^{-6} ~~to~~ 10^{-4}~~. For example, the PCB concentrations detected in resident fish from the Willamette and Columbia rivers (EVS 2000; EPA 2002a) are approximately 20 to 100 times higher than the EPA target fish tissue concentration, which is based on a target risk level of~~ 1×10^{-6}~~. Regional efforts are underway to reduce fish tissue concentrations. Sources contributing to regional tissue concentrations are unknown.~~

~~8.21.2.18 Shellfish Consumption~~

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~~The consumption of shellfish was evaluated for adult fishers, and breastfeeding infants of adult fishers, based on two consumption rates representing a range of potential consumption scenarios. Current and potential future shellfish consumption rates for the Site are not known. The shellfish species evaluated for consumption risks were crayfish and clams. Cumulative cancer risks from consumption of shellfish ranged from~~ 9×10^{-7} ~~to~~ 7×10^{-4}~~. Cumulative HIs for noncarcinogenic risk, ranged from 0.06 to 40 for consumption of shellfish. The maximum cumulative HI for a breastfeeding infant of a shellfish consumer is 800.~~

~~8.21.2.20 Direct Exposure to Beach Sediment~~

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~~Beaches were identified as potential human use areas associated with industrial upland sites (dockside workers), recreation (recreational users or fishers), and/or trespassing or transient use (transients). The extent to which each beach is~~

~~used and the nature of the contact with sediments/beach are uncertain. However, conservative assumptions were included in the risk analysis of this exposure pathway to provide an estimate of potential risks.~~

~~The cumulative cancer risks for all of the CT beach sediment exposure scenarios were below 10^{-4}. The CT scenarios for exposure to beach sediment resulting in risks above 1 x 10^{-6} were the dockside worker (6 x 10^{-6}), tribal fisher (2 x 10^{-6}), and combined adult and child, as well as child-only, recreational beach user (2 x 10^{-6}) scenarios. The RME scenarios for exposure to beach sediment resulting in cumulative cancer risks above 1 x 10^{-6} include: dockside worker, adult and child recreational beach user, tribal fisher, low-frequency fisher, and high-frequency fisher. None of the RME scenarios for exposure to beach sediment resulted in risks greater than 1 x 10^{-4} or cumulative HIs exceeding 1. Risks above 1 x 10^{-6} resulting from exposures to beach sediment are due at least in part to arsenic, which is likely present at naturally occurring background concentrations. For instance, the highest cumulative risk from exposure to beach sediment at beaches used by transients, for recreation, and/or by fishers is for the tribal fisher RME scenario (2 x 10^{-5}), and approximately 50 percent of this risk is associated with arsenic concentrations that are at or below the background arsenic concentration of 7 mg/kg (DEQ 2007). Carcinogenic PAHs were the only other contaminant identified as potentially posing unacceptable risks for beach sediment.~~

~~8.21.2.23 Direct Exposure to In-Water Sediment~~

~~Risks from in-water sediment exposure were estimated separately for each of the half-mile river segment exposure areas on each side of the river, and for Study Area-wide exposure. In-water sediments within the navigation channel were not included in the risk evaluation. Risks from in-water sediment exposure were evaluated for exposures by in-water workers, tribal fishers, fishers, divers, and breastfeeding infants of adults exposed to in-water sediment.~~

~~The cumulative risks for all of the CT scenarios were below 1 x 10^{-4}, and only the tribal fisher and breastfeeding infant CT scenarios had cancer risks above 1 x 10^{-6}. For the RME scenarios, cumulative cancer risks were greater than 1 x 10^{-6} but were below 1 x 10^{-4}, with the exception of cancer risks above 1 x 10^{-4} for direct exposure to in-water sediment by a tribal fisher and breastfeeding infant of a tribal fisher at exposure areas RM 6W (risk is 2 x 10^{-4} due primarily to cPAHs) and RM 7W (risk is 3 x 10^{-4} due primarily to dioxins). RM 7W also results in a cumulative HI greater than 1 for the tribal fisher (HI is 3), breastfeeding infant (HI is 5), and high frequency fisher (HI is 2) RME scenarios.~~

~~8.21.2.26 Direct Exposure to Surface Water~~

~~Risks were evaluated for direct surface water exposures by transients, divers and adult and child recreational beach users. The only scenarios resulting in cumulative~~

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~~cancer risks greater than 1 x 10^{-6} were the diver in wet suit (1 x 10^{-5}) and the diver in dry suit (2 x 10^{-6}) RME scenarios at RM 6W due primarily to cPAHs. None of the direct surface water exposure scenarios resulted in HIs greater than 1.~~

~~Risks were also evaluated for hypothetical exposure to untreated surface water used as a domestic water source by future residents. The maximum cumulative cancer risk for hypothetical exposure to untreated surface water was 9 x 10^{-4} for the combined adult/child RME scenario, due primarily to cPAHs, and benzo(a)pyrene specifically. The child RME scenario for hypothetical exposure to untreated surface water as a domestic water source was the only scenario with a HI that exceeded 1. The exceedance occurred at RM 8.5, primarily from exposure to 2-(4-chloro-2-methylphenoxy)propanoic acid (MCPP) (HQ for MCPP was 2).~~

~~8.21.2.29 Direct Exposure to Seeps~~

~~Risks from direct contact with groundwater seeps were evaluated for exposure by a transient for one exposure point. The transient exposure scenario did not result in cumulative cancer risks greater than 1 x 10^{-6} or HIs greater than 1.~~

~~8.21.2.31~~8.4.12 Identification of Contaminants Potentially Posing Unacceptable Risks

Contaminants were identified as potentially posing unacceptable risks if they resulted in a cancer risk greater than 1 x 10^{-6} or a HQ greater than 1 under any of the exposure scenarios for any of the EPCs evaluated in the BHHRA, regardless of the uncertainties. There were 33 contaminants identified as potentially posing unacceptable risks for the exposure scenarios listed above. Only a subset of these contaminants were associated with cancer risks exceeding 1 x 10^{-4} or HQs exceeding 1, and an even smaller number of contaminants contributed to most of the relative percentage of total risk. In some cases, the contaminants were identified as potentially posing unacceptable risks based only on the highest ingestion rate, a single exposure point, and/or the maximum detected concentration. Four of the contaminants (alpha-, beta-, and gamma-hexachlorocyclohexane and heptachlor) were identified as potentially posing unacceptable risks on the basis of N-qualified data only. The use of an “N” qualifier indicates that the identity of the analyte is not definitive. These four chemicals are not recommended for further evaluation of potential risks to human health. The remaining 29 contaminants identified as potentially posing unacceptable risks to human health are evaluated further in the Human Health Risk Management Recommendations document. These contaminants are presented in Table 8.4-2.

~~8.22~~8.5 UNCERTAINTY ANALYSIS

The presence of uncertainty is inherent in the risk assessment process, and EPA policy calls for numerical risk estimates to always be accompanied by descriptive information regarding the uncertainties of each step in the risk assessment to ensure an objective and

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Formatted: Heading 3, Outline numbered + Level: 3 + Numbering Style: 1, 2, 3, ... + Start at: 1 + Alignment: Left + Aligned at: 0.31" + Tab after: 1" + Indent at: 1" balanced characterization of the true risks and hazards. The term "uncertainty" is often used in risk assessment to describe what are, in reality, two conceptually different terms: uncertainty and variability. Uncertainty can be described as the lack of a precise knowledge resulting in a fundamental data gap. Variability describes the natural heterogeneity of a population. Uncertainty can sometimes be reduced or eliminated through further measurements or study. By contrast, variability is inherent in what is being observed. Although variability can be better understood, it cannot be reduced through further measurement or study, although it may be more precisely defined. However, the additional cost of further data collection may become disproportional to the reduction in uncertainty.

The risks and hazards presented are consistent with EPA's stated goal of RME representing the high end of the possible risk distribution, which is generally considered to be greater than the 90th percentile. However, these estimates are based on numerous and often conservative assumptions and, in the absence of definitive information, assumptions are used to ensure that actual sites risks are not underestimated. The cumulative effect of these assumptions can result in an analysis with an overall conservativeness greater than the individual components. Accordingly, it is important to note that the risks presented here are based on numerous conservative assumptions in order to be protective of human health and to ensure that the risks presented here are more likely to be overestimated rather than underestimated. A detailed analysis of the uncertainties associated with the BHHRA is found in Section 6 of Appendix F.

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~~Uncertainty is associated with every step of a risk assessment, from the sampling and analysis of chemicals in environmental media to the assessment of exposure and toxicity and the risk characterization. Uncertainty can have two components: 1) variability in data or information, and 2) lack of knowledge. The uncertainty analysis conducted as part of the BHHRA focused on issues of variability and knowledge uncertainty associated with each of the inputs and models used to derive the risk estimates. In general, the approach and methodologies used in a risk assessment are designed to provide a margin of conservatism in human health risk estimates.~~

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~~A detailed analysis of the uncertainties associated with the BHHRA is found in Section 6 of Appendix F. Uncertainties were evaluated relative to their potential impact on the conclusions of the BHHRA and resulting significance to risk management decisions. The following discussion presents the sources of uncertainty with the highest significance to risk management decisions.~~

Exposure Parameters for Fish and Shellfish Consumption Scenarios. Site-specific information regarding fish consumption is not available for Portland Harbor prior to its listing as a Superfund site. In the absence of site-specific data, fish consumption data representative from several sources w~~as~~ere considered and selected as being representative of the general population of the greater Portland area, as well as that portion of the population that actively fishes the Lower Willamette and utilizes fish from the river as a partial source of food. ~~Three different rates were evaluated: 17.5~~

~~grams per day (approximately 2 eight ounce meals per month), 49 g/ day (approximately 6 ½ eight ounce meals per month), and 142 g/day per day (19 eight ounce meals per month). 17.5 g/day is considered representative of a CT value for recreational fishers, and 49 g/day was selected as the RME value representing the higher-end consumption practices of recreational fishers. The consumption rate of 142 g/day represents a RME value for high levels of fish consuming, or subsistence, fishers.~~

~~The rates of 17.5 g/day and 142 g/day represent the 90th and 99th percentiles, respectively, of per capita consumption of uncooked freshwater/estuarine finfish and shellfish by individuals (consumers and non-consumers) 18 or older, as reported in the Continuing Survey of Food Intakes by Individuals (CSFII) and described in EPA's Estimated Per Capita Fish Consumption in the United States (EPA 2002b). However, t~~The rates presented in the CSFII study described in Section 8.2.4 represent per capita consumption rates rather than true long-term averaged consumption rates. ~~Further~~In addition, the large range between the percentile values is indicative of substantial variability in the underlying data. In addition to the consumption rates, uncertainty also exists with respect to the relative percentage of the diet of obtained from the Study Area or within individual exposure areas versus other nearby sources of fish, and the degree to which different methods of preparation and cooking may reduce concentrations of persistent lipophilic contaminants. ~~The exposure factors used in estimating potential human health risks were purposefully selected to be conservatively protective, and the range of fish consumption rates varied by an order of magnitude to reflect the uncertainty in consumption rates. Furthermore, assumptions about the species and tissue consumed, the source of fish, and lack of preparation methods add to the magnitude of uncertainty. These particular exposure assumptions are likely to overestimate actual exposure conditions at the Study Area and, therefore, overestimate human health risks and hazards.~~

Using the Maximum Concentration to Represent Exposure. In cases when there were fewer than five samples with a detected concentration for a given analyte for a given exposure area, the sample size was not sufficient to calculate a representative 95~~%~~ percent UCL on the mean, so the maximum concentration detected was used as the EPC. Data sets with fewer than 10 samples generally provide poor estimates of the mean concentration, defined as a large difference between the sample mean and the 95 percent UCL. In general, the UCL approaches the true mean as more samples are included in the calculation of the exposure concentration. ~~Using maximum detected concentrations of infrequently detected analytes to represent individual exposure areas, and especially Study Area-wide exposure, results in a conservative estimate of risk for the Study Area. The use of the maximum detected concentration likely overestimates the actual human health risks. The number of samples used to calculate EPCs for each scenario are listed in Tables 3-2 through 3-4 and 3-6 through 3-25 of Appendix F.~~

~~Risks from Background. Arsenic and mercury were found to result in risks greater than 1 x 10^{-6} or an HQ of 1 for at least one of the exposure scenarios evaluated in the~~

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~~BHHRA. Metals are naturally occurring chemicals and may be present in tissue, water or sediment due to background concentrations. For beach sediment, the arsenic EPCs ranged from 0.7 to 9.9 mg/kg and are consistent with the default background soil concentration for arsenic of 7 mg/kg used by DEQ (2007). In addition to naturally occurring metals, anthropogenic background may contribute to the overall risks. Further discussion of background concentrations is presented in Section 7.~~

~~Background tissue concentrations were not established for the Study Area, which increases the uncertainty in estimating risks from ingestion of tissue that are attributable to sources within the Study Area.~~

~~The risks were presented in the BHHRA without accounting for contributions from background, so it is important to recognize that background concentrations may result in unacceptable risks based on the exposure assumptions used in the BHHRA.~~

Regional Tissue Concentrations. PCBs and dioxins/furans have been detected in fish tissue collected in the Willamette and Columbia rivers, outside of the Study Area. In the Columbia River Basin Fish Contaminant Survey, the basin-wide average concentrations of total PCBs in resident fish ranged from 0.032 to 0.173 parts per million (ppm) for whole body samples and from 0.033 to 0.190 ppm for fillet with skin samples (EPA 2002a). In the middle Willamette River (RM 26.5 to 72), the average concentrations of total PCBs in resident fish ranged from 0.086 to 0.146 ppm for whole body samples and from 0.026 to 0.071 ppm for fillet with skin samples (EVS 2000). The regional tissue concentrations may be associated with unacceptable risks from fish consumption, especially at higher consumption rates. ~~These~~ However, these regional concentrations are lower than the concentrations detected in the Study ~~Area~~ Area, where average concentrations ranged from 0.16 to 2.8 ppm in whole body samples and from 0.17 to 2.5 ppm in fillet with skin samples (for PCBs as total congeners). The fish species included in the studies were different than those collected within the Study Area, so the concentrations may not be directly comparable. Sources contributing to the PCBs and dioxins/furans detected in fish collected outside of the Study Area are unknown and may not be relevant to the Study Area.

~~8.23~~8.6 SUMMARY AND CONCLUSIONS

The following presents the major findings of the BHHRA[1]:

- Risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment, surface water, or seeps. Risks and hazards from fish and shellfish consumption exceed the EPA point of departure for cancer risk of 1 x 10^{-4} and target HI of 1 when evaluated

[1] However, the identification of the contaminants presenting the most significant risk in various areas of the site consistent with EPA risk assessment guidance is not intended to suggest that other contaminants in those areas and at the site generally do not also present potentially unacceptable risk.

on a harbor-wide basis, and when evaluated on the smaller spatial scale by river mile.

- Consumption of resident fish species consistently results in the greatest risk estimates. Evaluated harbor-wide, the estimated RME cancer risks are 4 x 10^{-3} and 1 x 10^{-2} for recreational and subsistence fishers, respectively. Evaluated on a river mile scale, it is only at RM 5, where the estimated RME risk for recreational fishers is 9 x 10^{-5}, that the risk from consumption of resident fish is less than 1 x 10^{-4}. River miles associated with the highest estimated risk estimates are RM 4, RM 7, RM 11, and in Swan Island Lagoon. Evaluated harbor-wide and assuming a diet that consists of migratory fish in addition to resident fish species, the estimated RME cancer risk for tribal consumers is 1 x10^{-2} assuming fillet-only consumption, and 2 x 10^{-2} assuming whole body consumption.

- Noncancer hazard estimates for consumption of resident fish species are greater than 1 at all river miles. Evaluated harbor wide, the estimated RME HI is 300 and 1,000 for recreational and subsistence fisher, respectively. The highest hazard estimates are at RM 4, RM 7, RM 11, and in Swan Island Lagoon. The highest noncancer hazards are associated with nursing infants of mothers who consume resident fish from Portland Harbor. When fish consumption is evaluated on a harbor-wide basis, the estimated RME HI is 4,000 and 10,000 for infants of recreational and subsistence fishers, respectively. Evaluated on a harbor-wide scale, the estimated RME hazard for tribal consumers of migratory and resident fish is 600 assuming fillet-only consumption, and 800 assuming whole-body consumption. The corresponding HI estimates for nursing infants of mothers who consume fish are 8,000 and 9,000 respectively, assuming maternal consumption of fillet or whole-body fish.

- PCBs are the primary contributor to risk from fish consumption harbor wide. When evaluated on a river mile scale, dioxins/furans are a secondary contributor to the overall risk and hazard estimates. PCBs are the primary contributors to the noncancer hazard to nursing infants, primarily because of the bioaccumulative properties of PCBs and the susceptibility of infants to the developmental effects associated with exposure to PCBs.

- The largest source of uncertainty in the risk and hazard estimates includes the lack of good site-specific information about consumption of resident fish from Portland Harbor. Because tribal fish consumption practices were evaluated assuming a combined diet consisting of both resident and migratory fish, it not clear to what degree contamination in Portland Harbor contributes to those estimated risks. In addition, it is important to remember that the noncancer hazard estimates presented in the BHHRA are not predictions of specific disease, and the cancer estimates represent upper-bound values, and the EPA is reasonably confident that the actual cancer risks will not exceed the estimated risks presented in the BHHRA.

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- ~~Risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment, surface water, or groundwater seeps. Risks from fish and shellfish consumption are within or above the cumulative cancer risk range of 1 x 10^{-6} to 1 x 10^{-4} and exceed an HI of 1. With the exception of two half-mile river segments for the tribal fisher scenario and the hypothetical use of untreated surface water as a drinking water source by a future resident, direct contact with in-water sediment, surface water, and seeps results in risks within or below the EPA target cancer risk range of 1 x 10^{-6} to 1 x 10^{-4}. The evaluation of shellfish consumption was done at the direction of EPA.~~
- ~~Fish consumption is the exposure scenario that is considered the primary contributor to risk for the Study Area. PCBs are the primary contributor to risk for fish consumption, and dioxins/furans are a secondary contributor to risk for fish consumption. Risks from PCBs based on consumption of fish within the Study Area exceed the EPA target risk range of 1 x 10^{-6} to 1 x 10^{-4}, with a maximum estimated risk from PCBs of 7 x 10^{-2} for whole body consumption and 4 x 10^{-2} for fillet consumption. The maximum cancer risks from consumption of dioxins/furans in fish tissue are 7 x 10^{-3} for whole body tissue and 1 x 10^{-3} for fillet tissue.~~
- ~~The uncertainties associated with the tissue consumption scenarios should be considered when using the results of the BHHRA in risk management decisions. The fish tissue consumption risks in the BHHRA incorporate assumptions that may underestimate or more likely overestimate the actual risks.~~
- ~~The contribution of background sources of contaminants is an important consideration in risk management decisions. For example, approximately 50 percent of the highest risk to tribal fishers from exposure to beach sediment is associated with arsenic concentrations that are at or below the background arsenic concentration of 7 mg/kg (DEQ 2007).~~